QUANTIFICATION OF UNCERTAINTY USING POSSIBILITY THEORY: AN APPLICATION IN THE BIDDING DECISION OF IT SERVICE PROVIDERS

Synopsis of the Doctoral Thesis

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Doctor of Philosophy in Business Management

By

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Under the guidance of

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CERTIFICATE

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This is to certify that the thesis entitled "**Quantification of Uncertainty Using Possibility Theory: An Application in the Bidding Decision of IT Service Providers"**, submitted by Itishree Nayak to the Xavier Institute of Management Bhubaneswar, Xavier University, Bhubaneswar is a record of bona fide research work under our supervision and is worthy of consideration for the award of degree of Doctor of Philosophy in Business Management of the University.

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DECLARATION

I certify that

- The work content in the thesis is original and has been done by myself under the general supervision of my supervisor.
- The work has not been submitted to any other institute for any degree or diploma.
- I have followed the guidelines provided by the institute in writing the thesis.
- I have conformed to the norms and guidelines given in the manual of policies of the university.
- Whenever I have used materials (data, theoretical analysis, and text) from other sources, I have given due credit to them by citing them in the text of the thesis and giving their details in the references.
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Itishree Nayak

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1. Introduction

Most of the real-world decision-making problems are laden with uncertainties. The outcome of a decision is not known precisely and with certainty. Such lack of certainty renders the task of decision-making complex. Further, decision-making under uncertainty is influenced by factors such as cognitive biases, abilities, interests, and conflicting goals of decision-makers, organizational performance, and culture of the organization. Literature suggests that organizations lack rationality and consistency in making decisions that are subject to uncertainty.

In our thesis, we examine the challenges of decision-making under uncertainty, for information technology service provider (we will refer to as ITSPs henceforth) organizations. Literature suggests that information technology (IT) projects are subject to considerable uncertainties. Uncertainties associated with the IT projects have been well researched. However, most of these studies have taken into account the client's perspective and not that of the ITSP. The practice of outsourcing the IT projects is quite prevalent and ITSP organizations play a pivotal role in the successful development of outsourced IT projects. However, the uncertainties associated with ITSP organizations have not received due attention in the literature. In this backdrop, the present study attempts to bridge the research gap around the uncertainties faced by the ITSPs.

2. Literature Review

Information technology (IT) projects (also known as software projects) have a high rate of failure worldwide (Charette, 2005; Harvey Nash Group / KPMG International, 2016; Jun et al., 2011; Lehtinen et al., 2014). Researchers have observed that IT project

development involves considerable uncertainties that contribute to such a high failure rate of IT projects (Anandasivam et al., 2003; Aundhe & Mathew, 2009; Chen et al., 2009; Erdogmus, 2002). Uncertainties associated with the IT project development are examined in several studies (Boehm, 1991; Liu et al., 2010; Oz & Sosik, 2000; Ropponen & Lyytinen, 2000; Sharma & Gupta, 2012; Verner, 2007). Such studies discuss various perspectives on the uncertainty encountered in IT project development. Further, organizations can develop their IT projects in-house or chose to outsource to external vendors, i.e., ITSPs. Outsourcing may exacerbate some of the uncertainties associated with the development of the project. The uncertainty aspects of outsourced IT projects are well researched over the last few decades (Babar et al., 2007; Gefen et al., 2008; Gonzalez et al., 2010; Heiskanen et al., 2008; Levy, 2005; Mathew & Chen, 2013; Nakatsu & Iacovou, 2009; Pisello, 2001). However, most of these studies are based on the client's perspective. Very few studies have focussed on uncertainty from the perspective of the ITSP. The two sides may have different perceptions of uncertainty since their business goals are different (Jun et al., 2011). This dearth of studies signifies the need for further research on uncertainties faced by the ITSPs (Sá-Soares et al., 2014).

ITSPs get contractually engaged with the client to execute an IT project. In contract-based software development, often multiple ITSPs submit bids (Kitchenham B. et al., 2001). At the bidding stage, the project is at the conceptualization stage and the project requirements are not finalized. Hence, uncertainty is at its highest at the bidding stage (Jaafari, 2001; Kolltveit et al., 2004). Both the client and the ITSP form a broad level view of the project and proceed with certain assumptions. In the absence of enough information, the project bidders are exposed to several uncertainties. Such uncertainties may adversely impact the expected outcome of a project (Aundhe & Mathew, 2009). The ITSP needs to estimate the cost of executing the project at the bidding stage. Jørgensen (2005) observes a strong tendency of

software professionals to be overconfident and under-estimate the project cost. Such overconfidence is caused by an inadequate understanding of the uncertainty concepts, lack of feedback & evaluation, and the hidden agenda of the professionals. ITSPs often over-commit to win business in a highly competitive environment, leading to an over-optimistic schedule/budget and inflated client expectation. Under such circumstances, projects fail to succeed even when the best project management strategies are adopted (Taylor, 2006). The literature also suggests that incorrect assessment of uncertainties can severely impact the project delivery and the expected profit of the bidder (Anandasivam et al., 2003).

The bidding process of an ITSP involves multiple stakeholders, such as the executing team, the estimating team, the sales team, and the leadership. Researchers observed that the individuals associated with a project often have varied views on uncertainty and its acceptance (Kitchenham B. et al., 2001; Kitchenham B. et al., 2005; Kwak & LaPlace, 2005; Liu et al., 2010; Taylor, 2006). In a similar vein, conflict is observed between the executing team, the sales team, the estimating team, and the senior managers, over the cost and schedule estimation in IT project biddings (Kitchenham B. et al., 2001; Kitchenham B. et al., 2005; Taylor, 2006). Owing to information asymmetry and varied risk-taking attitude, the different stakeholders have diverse views about the uncertainties and their impact on the expected outcome of the project. Individuals may also be guided by the targets assigned to them at the cost of sacrificing organizational goals. Such scenarios lead to conflict in decision-making and further complicate the job of the decision-makers.

Further, uncertainty doesn't always imply a possibility of loss. The uncertainties may cause either negative or positive variation to the expected project outcome. The negative variations pose threats to the project, whereas, the positive variations are the opportunities for the bidders (Kolltveit et al., 2004; Marinho et al., 2013; Perminova et al., 2008). Managers should evaluate both the threat and opportunity for making balanced decisions (Ward &

Chapman, 2003). Hence, ITSPs not only need to be cognizant of the threats but also need to consider future opportunities associated with projects while deciding on whether to bid or not. A loss-making project may not always be undesirable. Such a project may be instrumental in generating considerable benefits in the long run, such as receiving more business from the client, developing competency in new technology or domain, increasing footprint in new geographies, and getting new clients through references. The ITSP needs to consider the possibility of future business while getting into a contractual agreement with the client (Anandasivam et al., 2003).

Hence, IT project bidding decisions are complex that need to judge the uncertainties, integrate the views of multiple stakeholders, and balance the threat and opportunities. Inadequate appreciation of uncertainties at the bidding stage can create problems throughout the project and sometimes even after the completion of the project. Therefore, addressing uncertainty is of paramount importance during the bidding process. Organizations cannot avoid uncertainty completely but need to decide on their acceptable level (Kwak & LaPlace, 2005) and capture them in the decision-making process (Mohamed & McCowan, 2001). Essentially, a better understanding of the uncertainties helps the bidder to make an informed decision and bid responsibly. The ITSP needs to evaluate the uncertainties to decide whether it is justified to go on board with a project or not. The moot question is, how the decision-makers can make the appropriate decision, giving due consideration to uncertainties, balancing threats and opportunities, and also taking into account the views of different stakeholders? This question forms the basic premise of our dissertation.

Researchers noticed that the issue of uncertainty is discussed largely in research but not adopted widely in practice. In some situations, uncertainty is captured in the process of collection of information, but not included properly in the final decision-making (Zotteri & Kalchschmidt, 2007). Researchers discussed the importance of the identification and

quantification of uncertainty for its inclusion in the decision-making process (Kadous et al., 2005; Kreye et al., 2012; Marinho et al., 2013; Speier, 2006).

We observed that the uncertainty associated with the IT projects is of an epistemic type, which is caused by the lack of information rather than the natural variation of the physical world. Literature has discussed various limitations of probability theory for handling epistemic uncertainty (Collan et al., 2009; Klir & Bo, 1995; Machacha & Bhattacharya, 2000; Polasky et al., 2011; Zadeh, 2002). Literature has also suggested several methods for quantifying epistemic uncertainty that are not based on the probability theory. These methods help to address the limitations of probability theory in the treatment of epistemic uncertainty. Some of these methods include imprecise probability (Walley, 1991), Minimax/ Maximin/ Maximax Regret functions (Dekay et al., 2002; Hurwicz, 1951; Savage, 1951; Wald, 1950), evidence theory (Dempster, 1967; Shafer G., 1976), real options analysis (Chen et al., 2009; Collan et al., 2009; Myers, 1974; Wu & Ong, 2008), interval analysis (Moore, 1966), and possibility theory (Zadeh, 1965). Possibility theory which is based on the mathematical foundations of a fuzzy set is suggested by researchers for its ability to handle real-life uncertainty problems. This theory allows us to model linguistic expressions on uncertainties, imprecise boundaries of objects in a set, ranges of possible outcomes than a fixed value, is based on inputs of experts, and does not need considerable past data. We find that the possibility theory may be more appropriate for the quantification of uncertainties keeping in view the nuances associated with IT projects at the bidding stage. We did not find such a method being used for quantification of uncertainties at the bidding stage for ITSPs.

3. Research Objective

Project bidding is a complex process for ITSPs. Limited information is available at this stage, thus exposing the service providers (bidders) to several uncertainties (Aundhe & Mathew, 2009). We observe a lack of an in-depth study of such uncertainties in the literature. In particular, the uncertainties at the IT project bidding stages are not detailed out. Further, ITSPs need to decide on the acceptable level of uncertainty in a bid. Incorrect decisions may lead to losses for the ITSP. The literature lacks substantial work in guiding ITSPs in bidding decisions through the evaluation of uncertainties. Hence, in our dissertation, we aim to assist the decision-makers in ITSP organizations in bidding decisions under uncertainty. In this backdrop, our first objective is to help the decision-makers, in the identification of the uncertainties and the opportunities at the bidding stage. Our first research question is defined as below.

RQ 1 - From the perspective of the ITSP, what are the various uncertainties to be considered at the bidding of an IT project?

Further, researchers suggested that uncertainty has two components (Kolltveit et al., 2004; Marinho et al., 2013; Perminova et al., 2008). The first component is the threat aspect that causes negative variation to the expected outcome of a project. The second component is the opportunity aspect that leads to positive variations in such project outcomes. Hence we define two sub-questions under our first research question as described below.

RQ 1.1 – What are the various uncertainties to be considered (by the ITSP) at the bidding stage that pose a threat to the expected outcome of an IT project?

RQ 1.2 – What are the various uncertainties to be considered (by the ITSP) at the bidding stage that offer an opportunity to the ITSP?

It is important to consider these uncertainties in decision-making, through quantification of uncertainty (Kreye et al., 2012; Mohamed & McCowan, 2001; Speier, 2006; Zotteri & Kalchschmidt, 2007). We argue that the uncertainty faced by ITSPs at the bidding stage is of epistemic type. The literature suggests that the traditional probability theory is not best suited for handling such type of uncertainty (Ayyub & Klir, 2006; Collan et al., 2009; Dubois, 2010; Klir & Bo, 1995; Machacha & Bhattacharya, 2000; Polasky et al., 2011; Zadeh, 2002). We find that the uncertainty quantification methods discussed in the literature for the ITSP are based on the probability theory. Hence, we decide to come up with a method for quantifying uncertainty that does not require probability values. The second research question is thus framed as follows.

RQ 2 - How to quantify the uncertainties associated with IT projects at the bidding stage, from the perspective of the ITSP, without using probability values?

We aim to bridge the research gap for the uncertainties of ITSPs by addressing these research questions. We suggest a decision-making framework that makes use of the outcome of our research questions. This framework is presented in Figure 1 followed by a brief explanation of the same.

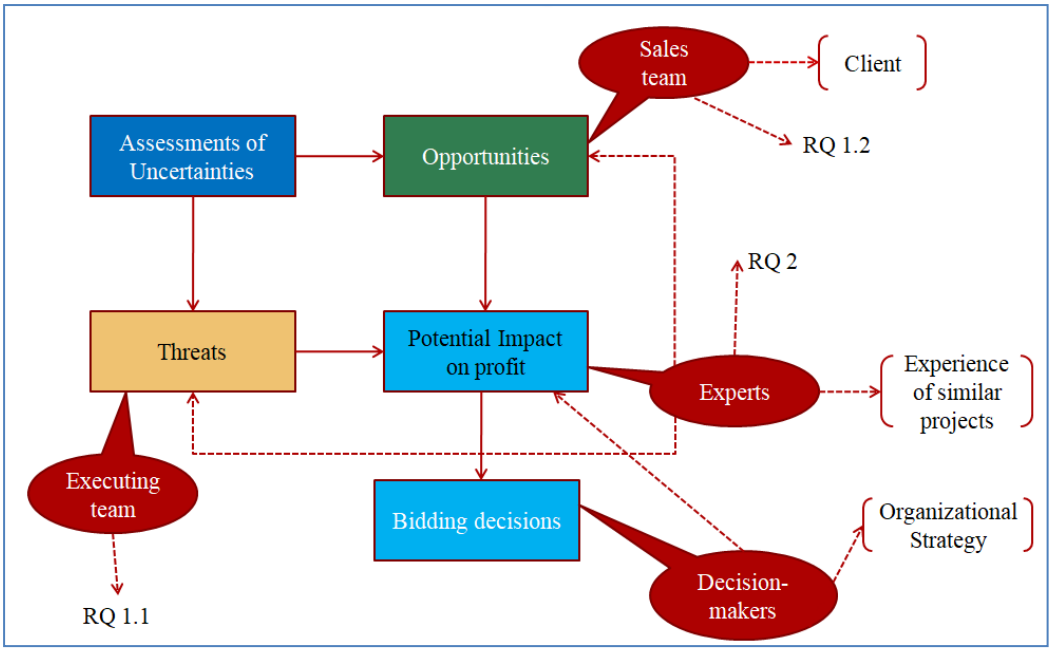

Figure 1: Decision-making framework

At the bidding stage, the cost is estimated by the ITSP in accordance with the information provided by the client. An ITSP has a certain expectation of profit from each bid. We assume that the profit is the difference between the price quoted for the bid and the cost estimated to execute the project. Our objective is that the decision-makers should visualize the potential variation to the expected profit due to the presence of uncertainties. As a first step to meet this objective, the uncertainties associated with the bid should be identified. As presented in Figure 1, uncertainty has a connotation for both threats and opportunities. The threat aspects should be assessed by the individuals (mostly project managers) representing the executing team. For this assessment, such individuals will refer to the outcome of RQ 1.1 as a guide. As a second step, the sales team will assess the opportunities that the bid may offer. For this assessment, the sales team will refer to the outcome of RQ 1.2 along with the information received from the client. As a third step, experts having experience of the execution of projects similar to the one being bid for will predict the variation to the expected profit. For their prediction, they will refer to the threats and opportunities identified in the previous steps, as well as their own experiences of similar projects. Experts will refer to our

quantification method (the outcome of RQ 2) to provide their assessment. Decision-makers will make the final decision on the bidding, based on the acceptability of the variation to the profit, following the organizational strategy.

4. Research Methodology

Our first and second research sub-questions are addressed through interviews with IT practitioners. We consider such an approach to be most appropriate as it helps to elicit maximum information while maintaining the focus. We planned to choose those practitioners who have substantial experience in the management of IT projects and the handling of the bidding process. We analyzed and presented the uncertainties at the bidding stage of IT projects through the sources of uncertainty, the uncertainty factors, the adverse consequences of these uncertainties, and their financial impacts. For addressing our second research question, we used the possibility theory to quantify the uncertainty. Possibility theory uses the mathematical computation of fuzzy sets. Fuzzy sets are characterized by their membership function. Out of different possible membership functions, we use the fuzzy trapezoidal function since it provides a balance between simplicity and the maximum use of available information. In a fuzzy trapezoidal membership function, the fuzzy variable being analyzed is represented as a range of four values (value in the best-case scenario, most likely value - upper limit, most likely value – lower limit, value in the worst-case scenario). Anandasivam et al. (2003) use project profit to characterize the performance of a project. We follow a similar approach and use project profit as a means to quantify uncertainty. We quantify uncertainty by computing the potential variation (both positive and negative) to the expected profit due to uncertainties.

5. Findings

Our findings brought out new insights to address the research questions. We identified 14 sources of uncertainty (technology, contractual clauses, Government policy, execution methodology, requirement related, estimation, client-related, pricing model, nature of the project, infrastructure readiness, country/location related, vendor/partner-related, transition, and ITSP capabilities) against seven sources previously identified in the literature. We discovered 56 unique uncertainty factors across these sources, considerably higher than the 29 unique factors listed in the previous literature.

Existing studies have stressed the need to identify opportunities. But they have not discussed such opportunities. We collated eight kinds of opportunities that ITSP should consider while bidding, namely, new geography, new client, competency building, competition, client relationship building, the commitment of future business, references for other clients, and criticality of the project for the client.

We applied our quantification method based on the possibility theory to three real IT projects (Project-1, Project-2, and Project-3). Our method suggested the potential variations to the estimated profit of the projects, based on the uncertainty assessment of experts. We present the outcome of our method for Project-1 in Figure 2 using the fuzzy trapezoidal membership function. For Project-1, at the bidding stage, the estimating team had estimated the profit to be between 780.55 K US$ to 1380.55 K US$. Our method suggested the project profit to be most likely between 511.6 K US$ and 1240.16 K US$ and it would not exceed 1286.45 K US$ and not fall below 415.02 K US$. Our method also identified a moderate possibility of the project not meeting the client's expectations. In that case, the total profit would be mostly between -62.6 K US$ (loss) and 119.5K US$ and it would not be below -122.97K US$ (loss) and at most be 148.45K US$. Hence, there is a possibility of Project-1

resulting in losses, without materialization of any future business from the client. We validated the efficacy of our method by comparing the findings from the application of our method with the actual outcome of Project-1. Most of the uncertainties identified at the bidding stage had an adverse impact on the project execution. Project-1 had considerable cost and schedule overruns. The client did not pay as per the contract, citing delivery issues. The actual profit realized from this project was only 65 K US$. This value falls between the range of values (-62.6 K US$ to 119.5 K US$) suggested by our method based on the possibility theory.

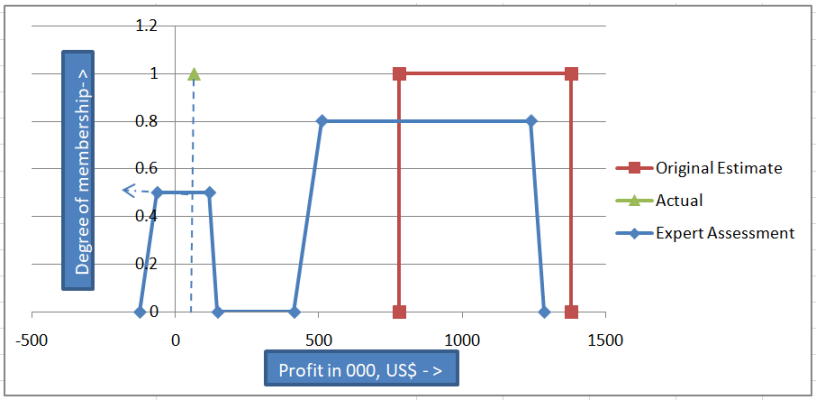

Figure 2: Expected profit of the project

Similar observations were made for Project-2 and Project-3. Our method was able to suggest variations to the estimated profit that matched with the actual profit with various degrees of possibilities. Hence, we conclude that using our possibility theory-based method ITSPs can quantify the uncertainties credibly.

6. Contribution of the Study

In our dissertation, we identified and presented the uncertainties of ITSP through four components. These components are defined as the source (origin) of uncertainty, uncertainty factors (attributes) associated with each source of uncertainty, consequences of these uncertainty factors, and impact (financial) of these consequences. These components,

structured in the form of a template, will contribute to the existing knowledge of the uncertainty aspects of the ITSP. Existing literature lacks such a detailed list of uncertainties linking the sources, uncertainty factors, consequences, and the impacts of the uncertainties on the ITSPs. Our research outcomes can be applied to bidding decisions in ITSP organizations. Decision-makers may use this list of uncertainties as a template for the assessment of uncertainty at the bidding stage. We also list various opportunities that the organization may consider in evaluating a bid. Additionally, we present the inter-relationship between different sources of uncertainty, which has only been partially discussed in the literature.

Our quantification method using possibility theory is a noteworthy contribution to the existing body of knowledge on ITSP uncertainties. To the best of our knowledge, possibility theory has not been used systematically in the decision-making of IT project bid. This study has considerable practical implications as well. ITSP organizations face challenges in bidding decisions due to the inherent uncertainty at the bidding stage. We expect that our proposed method will help address these uncertainties. Since our proposed method takes into account the perspectives of various key stakeholders, the decision making will be more broad-based. We expect that our method should help to avoid conflict between views of individual decision-makers. Using our method may also improve the accountability of the decision-makers. Failure of the project is often attributed to the project execution team, even when the failure is caused by incorrect bidding decisions. The method suggested by us may help ensure that employees are not held accountable for the poor performance of a project when it is a manifestation of a bad bidding-decision. The excel template created in this dissertation for the application and validation of our method can be used by IT practitioners, with adaption to the organizational context. Our quantification method may also be used for assisting in bidding decisions in other service industries with modification to the cost components as required.

7. Limitation

We observe that the accuracy of our method has a high dependency on the expert's association with similar projects in the past. If the organization does not have experts with relevant experiences, the accuracy of this method may be impacted. The expert's attitude towards uncertainty may also influence his assessment of the bid. A pessimistic expert may assign a higher possibility to worse case scenarios. Such an expert may as well predict a higher variation to the expected profit. If the experts suggest a very wide range of variation of the profit, the decision-makers may not find it useful. Some of the uncertainties may also be difficult to quantify, such as the natural calamities.

8. Future Research

The nature and complexity of IT projects keep changing due to the changing scenario of business complexity and technology. The uncertainties identified by us should periodically be reviewed and expanded. Researchers may try to prioritize the uncertainties and identify mitigation strategies for each of such uncertainties. The uncertainties identified by us are not specific to any particular kind of project. Researchers may identify uncertainties, failure points, and mitigation strategies for specific kinds of IT projects, such as digital transformation, bigdata, projects from specific industries (e.g., banks, retailing), and projects from specific geographies. We used the simple averaging method to aggregate the assessments of experts. The use of ordered waited averaging (OWA) method may be explored to see its efficacy over the simple averaging method. The reasons for IT project failure due to incorrect bidding decisions can be explored further by studying several such failed projects. Researchers may also explore the application of our proposed method for quantification of uncertainty for decision-making in other industries.

Bibliography

Adler, R. W. (2000). Strategic investment decision appraisal techniques: The old and the new. *Business Horizons* , 15-22.

Almeida, R. J., & Kaymak, U. (2009). Probabilistic fuzzy systems in value-at-risk estimation. *Intelligent Systems in Accounting, Finance and Management , 16*, 49-70.

Alter, S., & Ginzberg, M. (1978). Managing uncertainty in MIS implementation. *Sloan Management Rev.* , 23-31.

Alter, S., & Sherer, S. A. (2004). A general, but readily adaptable model of information system risk. *Communications of the Association for Information Systems* , 1-28.

Anandasivam, G., Konduru, S., M.S., K., & Mukhopadhyay, T. (2003). Contracts in offshore software development: An empirical analysis. *Management Science* , 1671-1683.

Angelis, L., & Stamelos, I. (2000). A simulation tool for efficient analogy based cost estimation. *Empirical Software Engineering , 5*, 35-68.

Armaneri, O., Ozdagoglu, G., & Yalcinkaya, O. (2010). An integrated decision support approach for project investors in risky and uncertain environments. *Journal of Computational and Applied Mathematics , 234*, 2530-2542.

Armaneria, Ö., Özdagoglu, G., & Yalçinkaya, Ö. (2010). An integrated decision support approach for project investors in risky and uncertain environments. *Journal of Computational and Applied Mathematics , 234*, 2530-2542.

Armour, H. O., & Teece, D. J. (1978). Organizational structure and economic performance: A test of the multidivisional hypothesis. *The Bell Journal of Economics , 9* (1), 106-122.

Arrow, K. (1965). Aspects of the theory of risk bearing. *Yrjö Jahnssonin Säätiö* .

Ascough, J., Maier, H., Ravalico, J., & Strudley, M. (2008). Future research challenges for incorporation of uncertainty in environmental and ecological decision-making. *ecological modelling* (219), 383-399.

Atkinson, R., Crawford, L., & Ward, S. (2006). Fundamental uncertainties in projects and the scope of project management. *International Journal of Project Management , 24*, 687-698.

Aundhe, M. D., & Mathew, S. K. (2009). Risks in offshore IT outsourcing: A service provider perspective. *European Management Journal* , 418-428.

Aven, T. (2010a). On the need for restricting the probabilistic analysis in risk assessments to variability. *Risk Analysis* , 354-360.

Aven, T. (2010b). Reply to discussants on “The Need for Restricting the Probabilistic Analysis in Risk Assessments to Variability". *Risk Analysis , 30*, 381-384.

Aven, T. (2012). The risk concept - Historical and recent development trends. *Reliability Engineering and System Safety , 99*, 33-44.

Aven, T., & Renn, O. (2009a). On risk defined as an event where the outcome is uncertain. *Journal of Risk Research* , 1-11.

Aven, T., & Renn, O. (2009b). The Role of quantitative risk assessment for characterizing risk and uncertainty and delineating appropriate risk management options, with special emphasis on terrorism risk. *Risk Analysis* , 587-600.

Aven, T., & Zio, E. (2014). Foundational issues in risk assessment and risk management. *Risk Analysis* , 1164 - 1172.

Ayyub, B. M., & Klir, G. J. (2006). *Uncertainty modeling and analysis in engineering and the sciences.* Boca Raton: Chapman & Hall/CRC, Taylor & Francis Group.

Babar, M. A., Verner, J. M., & Nguyen, P. T. (2007). Establishing and maintaining trust in software outsourcing relationships: An empirical investigation. *Journal of Systems and Software , 80* (9), 1438-1499.

Baird, I. S., & Thomas, H. (1985). Toward a contingency model of strategic risk taking. *Academy of Management Review , 10*, 230-245.

Barki, H., Rivard, S., & Talbot, J. (1993). An integrative contingency model of software risk management. *Journal of Management Information Systems , 17* (4), 203-225.

Bary, B. v., Westner, M., & Strahringer, S. (2018). Adding experts' perceptions to complement existing research on information systems backsourcing. *International Journal of Information Systems and Project Management , 6* (4), 17-35.

Bell, T. (1989). Managing Murphy's law: Engineering a minimum-risk system. *IEEE Spectrum , 26* (6), 24-27.

Bellman, R., & Zadeh, L. (1970). Decision making in a fuzzy environment. *Management Science , 17* (4), 141-164.

Beshears, J., & Gino, F. (2015). Leaders as decision architect. *Harvard Business Review* , 52-62.

Beynon, N., Curry, B., & Morgan, P. (2000). The Dempster-Shafer theory of evidence: An alternative approach to multicriteria decision modelling. *International Journal of Management Science , 28* (1), 37-50.

Bhattacharya, U., Rao, J., & Tiwari, R. (1992). Fuzzy multi-criteria facility location problem. *Fuzzy Sets and Systems , 51*, 277-287.

Bier, V. M., & Shi-Woei, L. (2013). On the treatment of uncertainty and variability in making decisions about risk. *Risk Analysis , 33* (10), 1899-1907.

Boehm, B. (1991). Software risk management: Principles and practices. *IEEE Software* , 32-41.

Boehm, B., Clark, B., Horowitz, E., & Westland, C. (1995). Cost models for future software life cycle processes. *Annals of Software Enginnering , 1*, 57-94.

Bolisani, E., & Bratianu, C. (2017). Knowledge strategy planning: An integrated approach to manage uncertainty, turbulence, and dynamics. *Journal of Knowledge Management , 21* (2), 233-253.

Bowman, E. H. (1980). A risk-return paradox for strategic management. *Slocm Management Review , 21* (3), 17-31.

Bowman, E. H. (1982). Risk seeking by troubled firms. *Sloan Management Beview , 23* (4), 33-42.

Bozeman, B., & Kingsley, G. (1998). Risk culture in public and private organizafions. *Public Administration Review* , 109-118.

Brechtel, S., Gindele, T., & Dillmann, R. (2014). Probabilistic decision-making under uncertainty for autonomous driving using continuous POMDPs. *IEEE 17th International Conference on Intelligent Transportation Systems (ITSC)*, (pp. 392-399). Qingdao, China.

Bush, A. A. (2008). An empirical investigation of the drivers of software outsourcing decisions in Japanese organizations. *Information and Software Technology* , 499–510.

Carruthers, B. G. (2013). From uncertainty toward risk: The case of credit ratings. *Socio-Economic Review , 11* (3), 525-551.

Charette, R. (2005). Why software fails. *IEEE Spectrum , 42* (9), 42-49.

Chen, T., Zhang, J., & Lai, K.-K. (2009). An integrated real options evaluating model for information technology projects under multiple risks. *International Journal of Project Management* , 776-786.

Cleden, D. (2009). *Managing project uncertainty.* Farnham, UK: Gower Publishing.

Collan, M., Fulle´r, R., & Mezei, J. (2009). A Fuzzy pay-off method for real option valuation. *Journal of Applied Mathematics and Decision Sciences* .

Davis, G. (1982). Strategies for information requirements determination. *IBM Systems Journal* , 4-30.

Dekay, M., Small, M., Fischbeck, P., Farrow, R., Cullen, A., Kadane, J., et al. (2002). Risk-based decision analysis in support of precautionary policies. *Journal of Risk Research , 5* (4), 391-417.

Dempster, A. (1967). Upper and lower probabilities induced by a multivalued mapping. *Annals of Mathematical Statistics , 38* (2), 325-339.

Dowie, J. (1999). Against risk. *Risk Decision and Policy , 4* (1), 57-73.

Dubois, D. (2010). Representation, propagation, and decision issues in risk analysis under incomplete probabilistic information. *Risk Analysis* , 1-9.

Dubois, D., & Prade, H. (1988). *Possibility theory, An approach to computerized processing of uncertainty.* New York: Plenum Press.

Dubois, D., Foulloy, L., Mauris, G., & Prade, H. (2004). Probability-possibility transformations, triangular fuzzy sets, and probabilistic inequalities. *Reliable Computing* , 273-297.

Durkheim, E. (1982). *The rules of the sociological method.* New York: Free Press.

Erdogmus, H. (2002). Valuation of learning options in software development under private and market risk. *The engineering Economist* , 308-353.

Erkoyuncu, J. A., Durugbo, C., & Roya, R. (2013). Identifying uncertainties for industrial service delivery: A systems approach. *International Journal of Production Research , 51* (21), 6295-6315.

Ferson, S., & Ginzburg, L. (1996). Different methods are needed to propagate ignorance and variability. *Reliability Engineering & System Safety , 54* (2-3), 133-144.

Garrick, B. (2010). Interval analysis versus probabilistic analysis. *Risk Analysis , 30* (3), 369-370.

Gefen, D., Wyss, S., & Lichtenstein, Y. (2008). Business familiarity as risk mitigation in software development outsourcing contracts. *MIS Quarterly , 32* (3), 531-551.

Georgescu, I. (2012). *Possibility theory and the risk.* Chennai: Scientific Publishing Services.

Ghosh, S., & Mujumdar, P. P. (2008). Climate change impact assessment: Uncertainty modeling with imprecise probability. *Journal of Geophysical Research , 114*, 1-17.

Giang, P. H. (2005). Two axiomatic approaches to decision making using Possibility theory. *European Journal of Operational Research , 162*, 450-467.

Gonzalez, R., Gasco, J., & Llopis, J. (2010). Information systems offshore outsourcing: An exploratory study of motivations and risks in large Spanish firms. *Information Systems Management , 27* (4), 340-355.

Hallowell, M. R., & Gambatese, J. A. (2010). Qualitative research: Application of the Delphi method to CEM research. *Journal of Construction Engineering and Management , 136* (1), 99-107.

Harrison, F. E. (1996). A Process perspective on strategic decision making. *Management Decision , 34* (1), 46-53.

Harvey Nash Group / KPMG International. (2016). *The creative CIO.* Harvey Nash / KPMG CIO Survey.

Heiskanen, A., Newman, M., & Eklin, M. (2008). Control, trust, power, and the dynamics of information system outsourcing relationships: A process study of contractual software development. *Journal of Strategic Information Systems , 17*, 268-286.

Hey, J. D., Lotito, G., & Maffioletti, A. (2010). The descriptive and predictive adequacy of theories of decision making under uncertainty/ambiguity. *Journal of Risk and Uncertainty , 41*, 81-111.

Hirsch, S., Burggraf, P., & Daheim, C. (2013). Scenario planning with integrated quantification – Managing uncertainty in corporate strategy building. *Foresight , 15* (5), 363-374.

Hirschey, M., & Pappas, J. (1998). *Fundamentals of managerial economics.* Chicago: Dryden Press.

Huang, X., Ho, D., Ren, J., & Capretz, L. F. (2007). Improving the COCOMO model using a neuro-fuzzy approach. *Applied Soft Computing* , 29-40.

Hurwicz, L. (1951). Optimality criteria for decision-making under ignorance. Chicago, Chicago, USA: Cowles Commission Discussion Paper.

ISO 31000. (2018). *Risk management - Principles and guidelines.* International Organization for Standardization.

Jaafari, A. (2001). Management of risks, uncertainties and opportunities on projects: Time for a fundamental shift. *International Journal of Project Management , 19*, 89-101.

Jauch, L. R., & Kraft, K. L. (1986). Strategic management of uncertainty. *Academy of Management Review , 11* (4), 777-790.

Jørgensen, M. (2004a). A review of studies on expert estimation of software development effort. *The Journal of Systems and Software , 70*, 37-60.

Jørgensen, M. (2005). Evidence-based guidelines for assessment of software development cost uncertainty. *IEEE Transactions on software engineering , 31* (11), 942 - 954.

Jørgensen, M. (2004b). Regression models of software development effort estimation accuracy and bias. *Empirical Software Engineering , 9*, 297-314.

Jørgensen, M., & Shepperd, M. (2007). A systematic review of software development cost estimation studies. *IEEE Transactions On Software Engineering , 33* (1), 33-53.

Jørgensen, M., & Sjoberg, D. (2003). An effort prediction interval approach based on the empirical distribution of previous estimation accuracy. *Information and Software Technology , 45* (3), 123-136.

Jun, L., Qiuzhen, W., & Qingguo, M. (2011). The effects of project uncertainty and risk management on IS development project performance: A vendor perspective. *International Journal of Project Management* , 923-933.

Jun, Y. B., Lee, K. J., & Zhan, J. (2008). Soft p-ideals of soft BCI-algebras. *Computers and Mathematics with Applications , 58*, 2060-2068.

Kadous, K., Koonce, L., & Towery, K. L. (2005). Quantification and pursuation in managerial judgement. *Contemporary Accounting Research* , 643-686.

Kahneman, D., & Lovallo, D. (1993). Timid choices and bold forecasts: A cognitive perspective on risk taking. *Management Science* , 17-31.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica* , 263-291.

Kahraman, C., Beskese, A., & Ruan, D. (2004). Measuring flexibility of computer integrated manufacturing systems using fuzzy cash flow analysis. *Information Sciences , 168*, 77-94.

Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. *Risk Analysis , 1* (1), 11-27.

Karhade, P., Shaw, M. J., & Subramanyam, R. (2015). Patterns in information systems portfolio prioritization: Evidence from decision tree induction. *MIS Quarterly , 39*, 413-433.

KarimiAzari, A., Mousavi, N., Mousavi, S. F., & Hosseini, S. (2011). Risk assessment model selection in construction industry. *Expert Systems with Applications , 38*, 9105-9111.

Kitchenham, B. A., Pickard, L., Linkman, S., & Jones, P. (2005). A framework for evaluating a software bidding model. *Information and Software Technology , 47*, 747–760.

Kitchenham, B., Pickard, L. M., Linkman, S., & Jones, P. W. (2003). Modeling Software Bidding Risks. *IEEE Transactions on engineering management , 29* (6), 542-554.

Kitchenham, B., Pickard, L., Linkman, S., & Jones, P. (2001). *A preliminary risk-based software bidding model.* England: Keele University Technical Report TR/SE-0103.

Klir, G. J., & Bo, Y. (1995). *Fuzzy sets and fuzzy logic.* Prentice-Hall Inc.

Knight, F. H. (1964). *Risk, uncertainty and profit.* Augustus M. Kelley.

Koller, G. (2000). *Risk modelling for determining value and decision making.* Chapman & Hall.

Kolltveit, B. J., Karlsen, J. T., & Grønhaug, K. (2004). Exploiting opportunities in uncertainty during the early project phase. *Journal of Management in Engineering , 20* (4), 134-140.

Kothari, C. (2004). *Research methodology methods and techniques.* New Age International Private Limited.

Kreye, M., Goh, Y., Newnes, L., & Goodwin, P. (2012). Approaches to displaying information to assist decisions under uncertainty. *Omega* , 682 - 692.

Kwak, Y. H., & LaPlace, K. S. (2005). Examining risk tolerance in project-driven organization. *Technovation* , 691-695.

Lacity, M. C., Khan, S. A., & Willcocks, L. P. (2009). A review of the IT outsourcing literature: Insights for practice. *Journal of Strategic Information Systems* , 130-146.

Lehtinen, T. O., Mäntylä, M. V., Vanhanen, J., Itkonen, J., & Lassenius, C. (2014). Perceived causes of software project failures – An analysis of their relationships. *Information and Software Technology* , 623-643.

Leifer, R., McDermott, C. M., O'Connor, G. C., Peters, L. S., Rice, M. P., & Robert W. Veryzer, J. (2000). *Radical innovation: How mature companies can outsmart upstarts.* Harvard Business School Press.

Levy, D. L. (2005). Offshoring in the new global political economy. *Journal of Management Studies , 42* (3), 685-693.

Li, D., Tang, H., Xue, S., & Su, Y. (2018). Adaptive sub-interval perturbation-based computational strategy for epistemic uncertainty in structural dynamics with evidence theory. *Probabilistic Engineering Mechanics , 53*, 75-86.

Li, Y., Xie, M., & Goh, T. (2009). A study of project selection and feature weighting for analogy based software cost estimation. *The Journal of Systems and Software , 82*, 82.

Lichtenstein, S., & Newman, J. (1967). Empirical scaling of common verbal phrases associated with numerical probabilities. *Psychonometric Science , 9*, 563–564.

Lipshitz, R., & Strauss, O. (1997). Coping with uncertainty: A naturalistic decision-making analysis. *Organizational Behavior And Human Decision Processes , 69* (2), 149-163.

Liu, B., & Liu, Y.-K. (2002). Expected value of fuzzy variable and fuzzy expected value models. *IEEE Transactions on Fuzzy System , 10* (4), 445-450.

Liu, S., Zhang, J., Keil, M., & Chen, T. (2010). Comparing senior executive and project manager perceptions of IT project risk: A Chinese Delphi study. *Information systems journal , 20*, 319-355.

Lopez-Martin, C., Claudia, I., & Chavoya, A. (2012). Software development effort prediction of industrial projects applying a general regression neural network. *Empirical Software Engineering* , 738–756.

Lyytinen, K., Mathiassen, L., & Ropponen, J. (1998). Attention shaping and software risk - A categorical analysis of four classical risk management approaches. *Information Systems Research* , 233-255.

MacCormack, A., & Verganti, R. (2003). Managing the sources of uncertainty: Matching process and context in software development. *Product Development & Management Association , 20*, 217–232.

Machacha, L. L., & Bhattacharya, P. (2000). A fuzzy-logic-based approach to project selection. *IEEE Transactions on Engineering Management , 47* (1), 65-73.

Marinho, M., Sampaio, S., & Moura, H. (2013). An approach related to uncertainty in software projects. *IEEE International Conference on Systems, Man, and Cybernatics* (pp. 894-899). Recife, PE, Brazil: Federal University of Pernambuco.

Markowitz, H. (1952). Portfolio selection. *Journal of Finance , 7* (1), 77-91.

Martin, W. (2006). *Theories of Judgment: Psychology, Logic, Phenomenology (Modern European Philosophy).* Cambridge: Cambridge University Press.

Mathew, S. K. (2006). Understanding risk in IT outsourcing: A fuzzy framework. *Journal of Information Technology Case and Application Research , 8* (3), 27-39.

Mathew, S. K., & Chen, Y. (2013). Achieving offshore software development success: An empirical analysis of risk mitigation through relational norms. *Journal of Strategic Information Systems* , 298-314.

McLain, D. (2009). Quantifying project characteristics related to uncertainty. *Project Management Journal , 40* (4), 60-73.

Mengel, F., Tsakas, E., & Vostroknutov, A. (2016). Past experience of uncertainty affects risk aversion. *Experimental Economics , 19*, 151-176.

Meyer, A. D., Loch, C. H., & Pich, M. T. (2002). Managing project uncertainty: From variation to chaos. *MIT Sloan Management Review* , 60-67.

Miles, M. B., & Huberman, A. (1994). *Qualitative data analysis: An expanded sourcebook.* SAGE Publications.

Miorando, R. F., Ribeiro, J. L., & Cortimiglia, M. N. (2014). An economic–probabilistic model for risk analysis in technological innovation projects. *Technovation* , 485-498.

Mishra, S., Gregson, M., & Lalumi`ere, M. L. (2012). Framing effects and risk-sensitive decision making. *British Journal of Psychology* , 83-97.

Mohamed, S., & McCowan, A. K. (2001). Modelling project investment decisions under uncertainty using possibility theory. *International Journal of Project Management , 19*, 231-241.

Moore, R. E. (1966). *Interval analysis.* Englewood Cliffs: Prentice-Hall.

Mousavi, S., & Gigerenzer, G. (2014). Risk, uncertainty, and heuristics. *Journal of Business Research , 67*, 1671-1678.

Myers, S. C. (1974). Interactions of corporate finance and investment. *Journal of Finance , 29* (1), 1-25.

Nakatsu, R. T., & Iacovou, C. L. (2009). A comparative study of important risk factors involved in offshore and domestic outsourcing of software development projects: A two-panel Delphi study. *Information & Management* , 57-68.

Nelson, R. R. (2007). IT project management: Infamous failures, classic mistakes, and best practices. *MIS Quarterly Executive , 6* (2), 67-77.

Nguyen, H. T., Kreinovich, V., & Wu, B. (1999). Fuzzy probability ~ fractal smooth. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems , 7*, 363-370.

Nooraie, M. (2008). Decision magnitude of impact and strategic decision-making process output. *Management Decision* , 640-655.

Oehmen, J., Locatelli, G., Wied, M., & Willumsen, P. (2020). Risk, uncertainty, ignorance and myopia: Their managerial implications for B2B firms. *Industrial Marketing Management , 88*, 330-338.

Oxford dictionary of English (3rd ed.). (2010). NewYork: OXFORD University Press.

Oz, E., & Sosik, J. J. (2000). Why information systems projects are abandoned: A leadership and communication theory and exploratory study. *Journal of Computer Information Systems , 41* (1), 66-78.

Pahariya, J., V., R., & M., C. (2010). Software cost estimation using computational intelligence techniques. *IEEE Xplore* .

Pal, D. R., McFall, K. S., & Subramanian, G. H. (2013). Software effort estimation using a neural network ensemble. *Journal of Computer Information Systems* , 49-58.

Park, H., & Baek, S. (2008). An empirical validation of a neural network model for software effort estimation. *Expert Systems with Applications* , 929-937.

Perminova, O., Gustafsson, M., & Wikstro¨m, K. (2008). Defining uncertainty in projects – A new perspective. *International Journal of Project Management* , 73-79.

Petit, Y. (2012). Project portfolios in dynamic environments: Organizing for uncertainty. *International Journal of Project Management , 30*, 539-553.

Pisello, T. (2001). *IT value chain management – Maximizing the ROI from IT investments.* United States of America: Alinean, LLC.

Platt, M. L., & Huettel, S. A. (2008). Risky business: the neuroeconomics of decision making under uncertainty. *Nature Neuroscience , 11* (4), 398-403.

Polasky, S., Carpenter, S. R., Folke, C., & Keeler, B. (2011). Decision-making under great uncertainty: Environmental management in an era of global change. *Trends in Ecology and Evolution , 26* (8), 398-404.

Project Management Institute, P. (2017). *A guide to the project management body of knowledge (PMBOK guide).* Project Management Institute.

Rajkumar, T., & Mani, R. (2001). Offshore software development the view from Indian suppliers. *Information Systems Management , 18* (2), 63-74.

Rebiasz, B. (2007). Fuzziness and randomness in investment project risk appraisal. *Computers and Operations Research , 34*, 199-210.

Ropponen, J., & Lyytinen, K. (2000). Components of software development risk:. *IEEE Transactions on Software Engineering , 26* (2), 98-112.

Rosa, E. A. (1998). Metatheoretical foundations for post-normal risk. *Journal of Risk Research , 1* (1), 15-44.

Roy, C. J., & Oberkampf, W. L. (2011). A comprehensive framework for verification, validation, and uncertainty quantification in scientific computing. *Computer Methods in Applied Mechanics and Engineering* (200), 2131-2144.

Samson, S., Reneke, J. A., & Wiecek, M. M. (2009). A review of different perspectives on uncertainty and risk and an alternative modeling paradigm. *Reliability Engineering & System Safety , 94* (2), 558-567.

Sandhu, P. S., Prashar, M., Bassi, P., & Bisht, A. (2009). A model for estimation of efforts in development of software systems. *International Journal of Computer, Electrical, Automation, Control and Information Engineering* .

Sá-Soares, F. d., Soares, D., & Arnaud, J. (2014). A catalog of information systems outsourcing risks. *International Journal of Information Systems and Project Management , 2* (3), 23-43.

Savage, L. (1951). The theory of statistical decision. *Journal of the American Statistical Association , 46* (253), 55-67.

Schjaer-Jacobsen, H. (2002). Representation and calculation of economic uncertainties: Intervals, fuzzy numbers, and probabilities. *Production Economics* , 91-98.

Serguieva, A., & Hunter, J. (2004). Fuzzy interval methods in investment risk appraisal. *Fuzzy Sets and Systems* , 443-466.

Shafer, G. (1976). *A mathematical theory of evidence.* Princeton: Princeton University Press.

Sharma, A., & Gupta, A. (2012). Impact of organisational climate and demographics on project specific risks in context to Indian software industry. *International Journal of Project Management , 30*, 176-187.

Shenhar, A. J., & Dvir, D. (2007). *Reinventing project management: The diamond approach to successful growth and innovation.* Harvard Business Press.

Shenhar, A. J., & Dvir, D. (2007). *Reinventing Project Management: The Diamond Approach to Successful Growth and Innovation.* United states: Harvard Business Press.

Sherer, S. (1989). Measuring the risk of software failure: A financial application. *Tenth International Conference on Information Systems,* (pp. 237-245). Boston: ACM/SlMfTIMS.

Singh, J. V. (1986). Performance, slack, and risk taking in organizational decision making. *Academy of Management Journal* , 562-585.

Sitkin, S. B., & Pablo, A. L. (1992). Reconceptualizing the determinants of risk behavior. *Academy of Management Review* , 9-38.

Sitkin, S. B., & Weingart, L. R. (1995). Determinants of risky decision-making behavior: A test of the mediating role of risk perceptions and propensity. *Academy of Management Journal* , 1573-1592.

Skinner, R., Nelson, R. R., & Chin, W. W. (2015). The delphi method research strategy in studies of information systems. *Communications of the Association for Information Systems , 37* (2).

Solaiman, B., & Bossé, É. (2019). *Possibility Theory for the Design of Information Fusion Systems.* Springer, Cham.

Speier, C. (2006). The influence of information presentation formats on complex task decision-making performance. *International Journal of Human-Computer Studies , 64* (11), 1115-1131.

Stephens, D. W. (1981). The logic of risk-sensitive foraging preferences. *Animal Behaviour , 29*, 628-629.

Su, H.-T., & Tung, Y.-K. (2012). Minimax expected opportunity loss: A new criterion for risk-based decision making. *The Engineering Economist* , 247-273.

Tah, J., & Carr, V. (2000). A proposal for construction project risk assessment using fuzzy logic. *Construction Management and Economics* , 491-500.

Tan, Y., Liyin Shen, W. L., & Shen, Q. (2008). Multiple-objective bidding strategy using goal programming technique. *Management Decision* , 656-672.

Taylor, H. (2006). Critical risks in outsourced IT projects: the intractable and the unforeseen. *Communications of the ACM , 49* (11), 75-79.

Teece, D. J., Peteraf, M. A., & Leih, S. (2016). Dynamic capabilities and organizational agility: Risk, uncertainty, and strategy in the innovation economy. *California Management Review , 58* (4), 13-35.

Troffaes, M. C. (2007). Decision making under uncertainty using imprecise probabilities. *International Journal of Approximate Reasoning , 45*, 17 - 29.

Tversky, A., & Kahneman, D. (1992). Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty* , 297-323.

Verhoef, C. (2005). Quantifying the value of IT-investments. *Science of Computer Programming* , 315-342.

Verner, J. E. (2007). State of the practice: An exploratory analysis of schedule estimation and software project success prediction. *Information & Software Technology , 49*, 181-193.

Vicki, M. B., & Lin, S.-W. (2013). On the treatment of uncertainty and variability in making decisions about risk. *Risk Analysis* , 1899-1907.

Vindoh, S., & Balaji, S. (2010). Fuzzy logic based leanness assessment and its decsion support system. *International Journal of Production Research , 49* (13), 4027-4041.

Wald, A. (1950). *Statistical decision functions.* New York: John Wiley & Sons.

Walley, P. (1991). *Statistical reasoning with imprecise probabilities.* London: Chapman & Hall.

Walls, M. R. (2005). Measuring and utilizing corporate risk tolerance to improve investment decision making. *The Engineering Economist* , 361-376.

Wang, J. (2009). Research on project selection system of pre-evaluation of engineering design project bidding. *International Journal of Project Management* , 584-599.

Wang, X., & He, Y. (2016). Learning from uncertainty for Big Data. *IEEE Systems, Man, & Cybernetics Magazine* , 26-32.

Ward, S., & Chapman, C. B. (1988). Developing competitive bids: A framework for information processing. *Journal of the Operational Research Society , 39* (2), 123-134.

Ward, S., & Chapman, C. (2003). Transforming project risk management into project uncertainty management. *International Journal of Project Management , 21*, 97-105.

Wazed, M. A., Ahmed, S., & Yusoff, N. (2009). Uncertainty factors in real manufacturing environment. *Australian Journal of Basic and Applied Sciences , 3* (2), 342-351.

Wideman, R. (1986). Risk management. *Project Management Journal , 17* (4), 20-26.

Wierman, M. J. (2010). *An introduction to the mathematics of uncertainty.* Center for Mathematics of Uncertainty.

Wu, D. D., Zhang, Y., Wu, D., & Olson, D. L. (2010). Fuzzy multi-oblective programming for supplier selection and risk modeling: A possibility approach. *European journal of Operational Research* , 774-787.

Wu, L.-C., & Ong, C.-S. (2008). Management of information technology investment: A framework based on a Real Options and Mean–Variance theory perspective. *Technovation* , 122-134.

Xie, G., Zhang, J., & Lai, K. (2006). Risk avoidance in bidding for software projects based on life cycle management theory. *International Journal of Project Management , 24*, 516 - 521.

Yager, R. (1988). Ordered weighted averaging aggregation operators in multi-criteria decision making. *IEEE Transactions on Systems, Man, and Cybernetics* (18), 183-190.

Zacharias, O. (2014). Project risk ranking in large-scale programs: a fuzzy set based approach. *Asia-Pacific Journal of Operational Research , 31* (3), 1450020 (22 pages).

Zadeh, L. (1965). Fuzzy sets. *Information and Control , 8* (3), 338-353.

Zadeh, L. (1977). Fuzzy sets as a basis for a theory of Possibility. *Fuzzy Sets and Systems* , 9-34.

Zadeh, L. (2002). Toward a perception-based theory of probabilistic reasoning with imprecise probabilities. *Journal of Statistical Planning and Inference , 105*, 233-264.

Zimmermann, H. (2010). Fuzzy set theory. *John Wiley & Sons, Inc* , 317, 332.

Zotteri, G., & Kalchschmidt, M. (2007). Forecasting practices: Empirical evidence and a framework for research. *International Journal of Production Economics , 108* (1-2), 84-99.